

Human-Robot Exploration - Missing Ingredients

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Human-robot system – who contributes what?

- **Robots contribute what humans lack in**
 - sensing
 - physical strength, accuracy, consistency...
 - withstanding adverse environment
 - specialized intelligence...
- **Humans contribute abilities to**
 - see the “big picture”
 - change tasks & criteria
 - apply diverse knowledge, generalize
 - improvise, take risk, compromise, gamble...

Does human-robot exploration differ from factory robotics?

It does, because of

... *peer-team* rather than *master-slave relationship*

... *unstructured* rather than *structured environment*
– it cannot be designed or modified

unstructured tasks are zillion, with strong
top-level functional commonality:
battlefield, space, undersea, office, hospital, farm ...

Ingredients that are missing

... and that require long-range extensive research:

1. *Cognitive science* - studying limitations of human skills (e.g. in spatial reasoning)
2. *Tele-presence* - giving the human a feel of “being there”
3. *Sensing* - in particular, *whole-body sensing* - to endow robots with enough sensing for adequate feedback and reaction to the environment

... plus sufficient on-board intelligence

Missing ingredients

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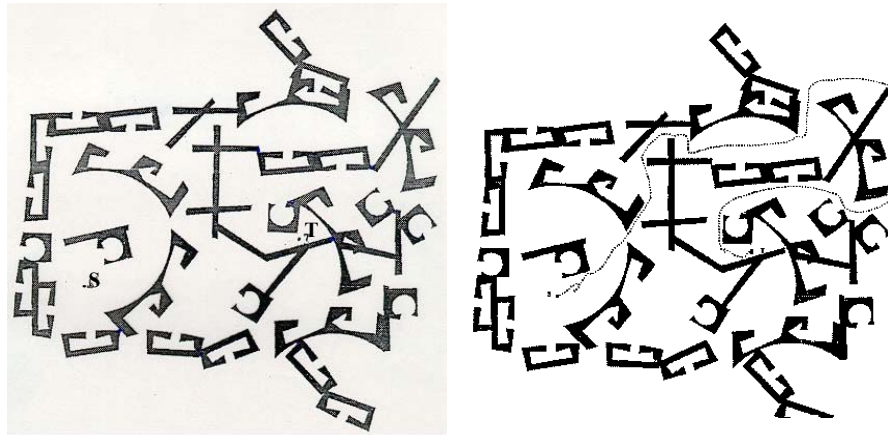
Teleoperation - cognitive side

... human spatial reasoning skills are limited.

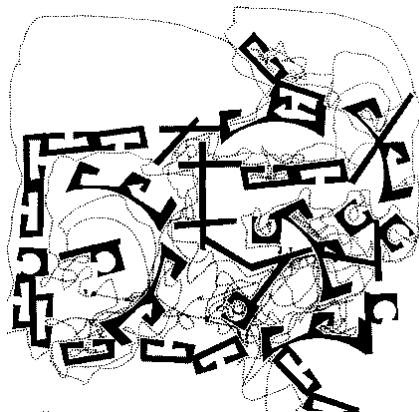
Intelligence is needed on the robot side.

**Motion planning for a small vehicle;
bird's view of the environment**

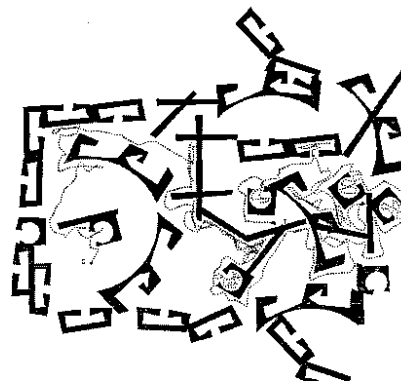
Here, human spatial reasoning is acceptable



**... But, if the human “is in the maze”,
their performance is hardly acceptable**



Ex.: subject 1



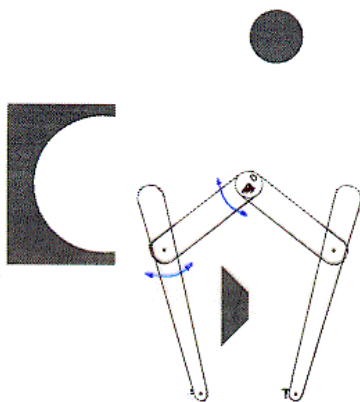
Ex.: subject 2

For humans, planning motion for a robot arm manipulator is much harder than for a mobile robot. ...and it gets only harder if the manipulator moves amongst obstacles

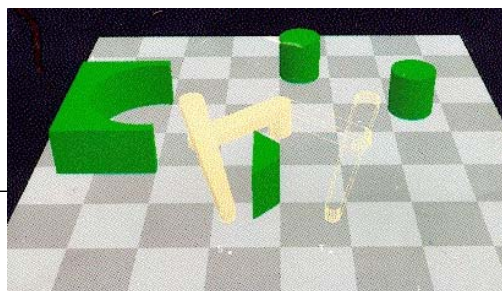
Simple 2D two-link manipulator



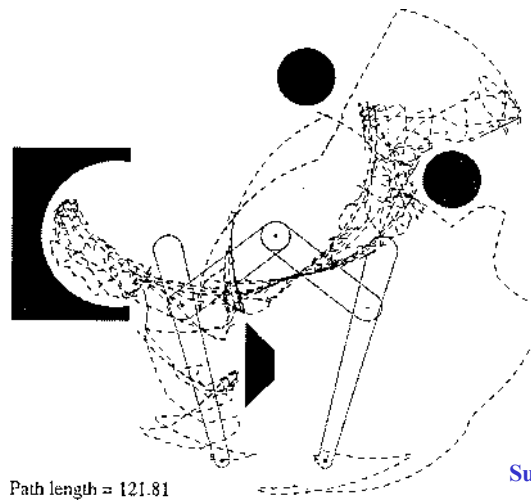
Same, virtual, 2D



Same, 2D+

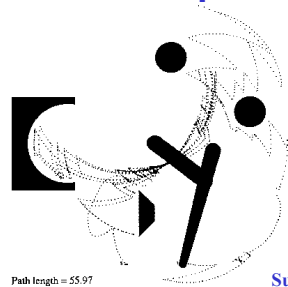


Human performance in 2D manipulator control

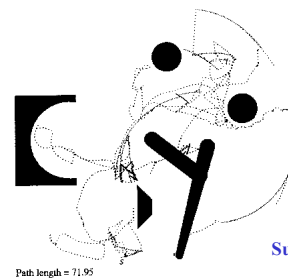


Subject 1

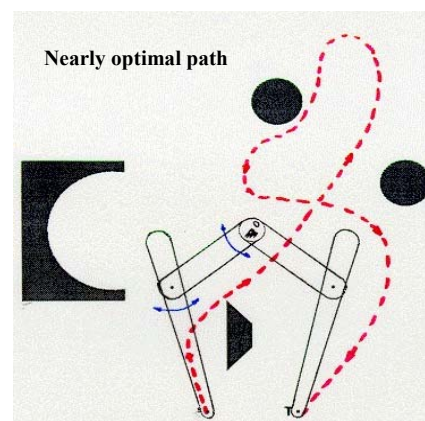
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Subject 2

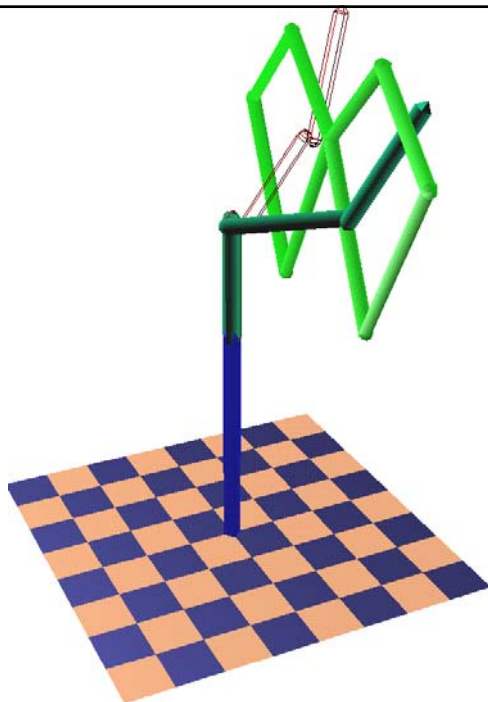
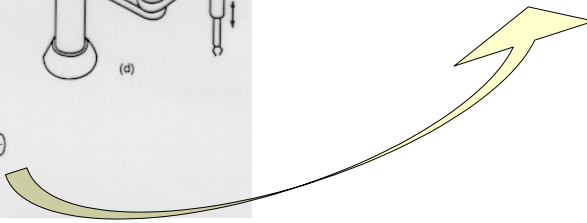
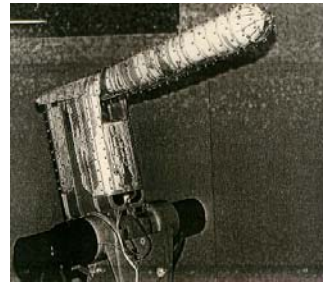
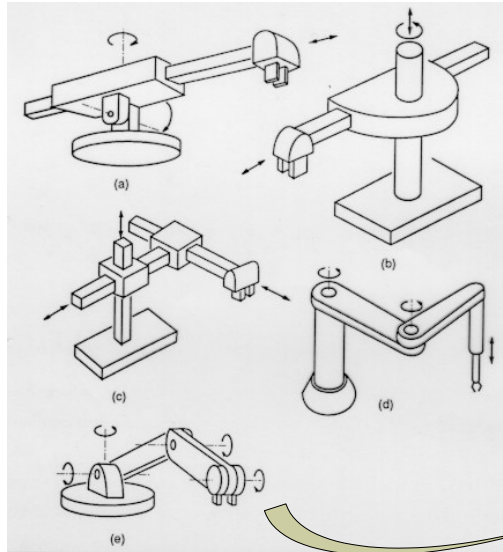


Subject 3

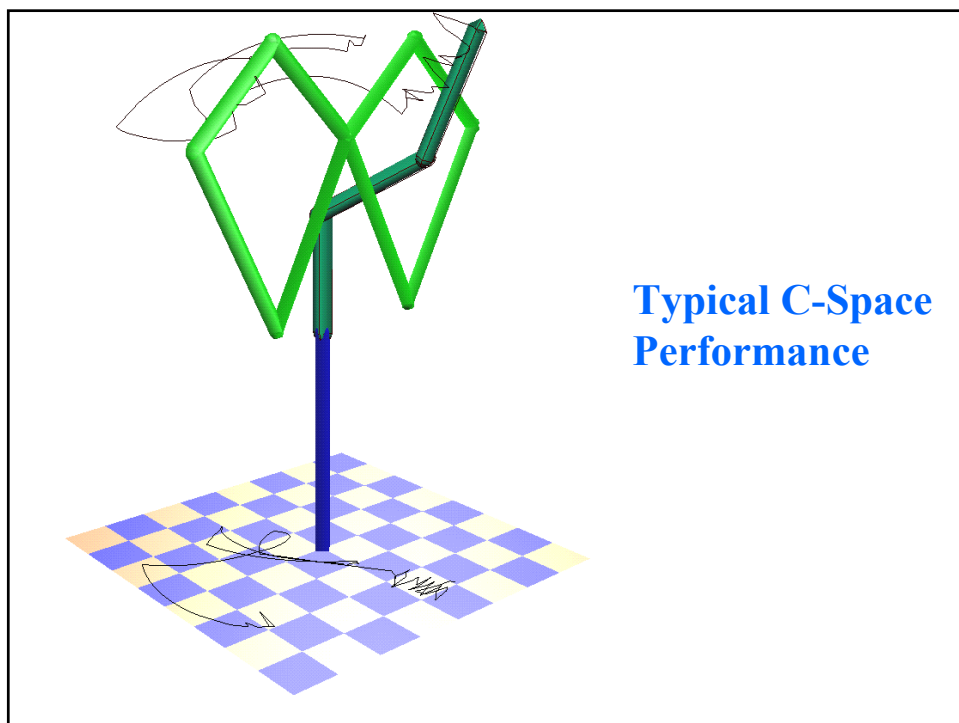
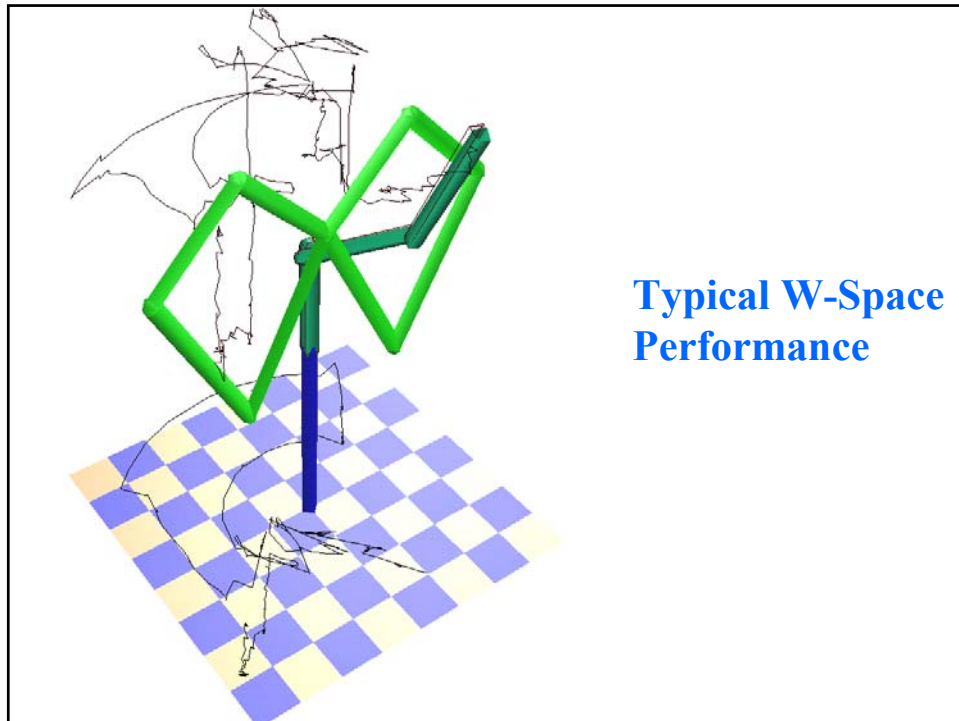


Robot intelligence and whole-body robot sensing are needed to help the human

Motion planning in 3D is harder than in 2D



W-Space Task

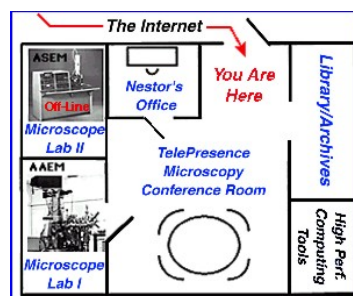


Missing ingredients

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Tele-presence

- Enable the user with an ability to observe/ monitor a remote site



- ... to view operations at a site - e.g. a microscope room, status screens, data being recorded by various systems

Tele-presence

... to see a remote site through the eyes of a robot



Telepresence Research, Inc

Tele-operation

- Let the user manipulate objects remotely
- ... or command robot motion amongst obstacles



Telerobot
U. Western Australia

Tele-immersion

Project one's
physical presence
onto a remote cite



National Tele-Immersion Initiative
- U. North Carolina at Chapel Hill

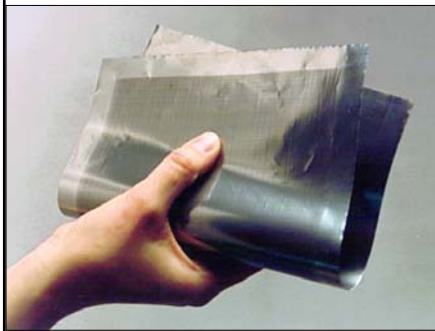
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Intelligent Sensing

- Goal – intelligent handling of *unstructured tasks*: in battlefield, office, hospital, farm, space, undersea...
- Such systems – autonomous or tele-operated - need *whole-body sensing*, an equivalent of *sensitive skin*
- Such devices create and process large amounts of information - hence belong to *information technology*

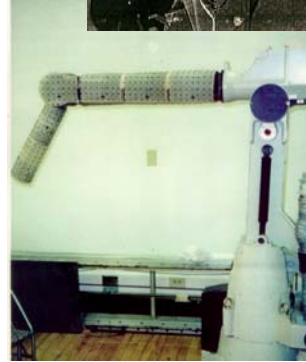
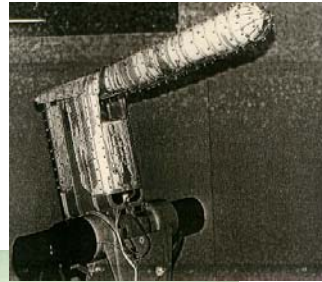
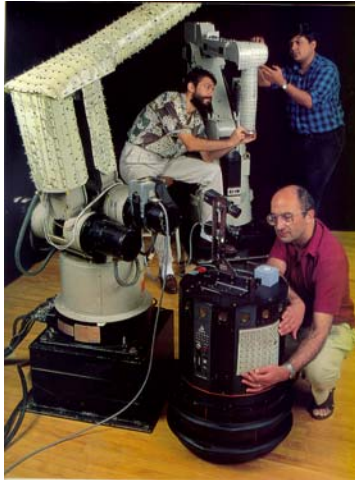
Humans will not be able to share the same environment with robots without mature sensitive skin technology



S. Wagner, Princeton U.



V. Lumelsky, U. Wisconsin



V. Lumelsky, U. Wisconsin

Smart Matter at PARC: Air-jet object mover (active surface)

Scalable computation, control,
communication, electronics

576 actuators



32K analog
sensing
elements

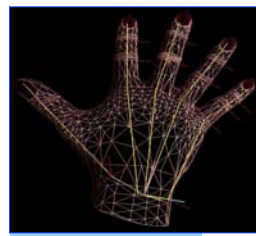


Supported in part
by DARPA MEMS program

Inexpensive batch fabrication
on PC board substrate
at meso scale (1 ft²)

parc X

Technology Integration Creating New Products



Data Processing

DARPA/NSF,
Academia
and Industry



Sensors



Sensitive Skin



Skin-like Material w/ TFTs

Potential Products

- Identification - security, personal networking
- Control - robotics, telemanipulation
- Smart products housing

S. Ghaem, MOTOROLA

High Volume Manufacturing

Low Cost Flex



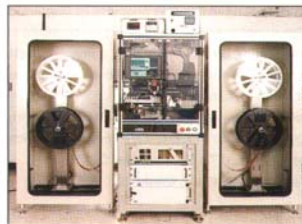
Conformal Devices



Shielding



Reel-to-Reel Assembly Line



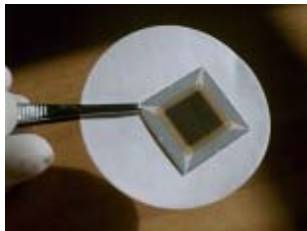
Advanced Manufacturing Technologies Efforts:

- Develop equipment and processes to handle conformal devices
- Develop high yield reel-to-reel assembly process for conformal devices

S. Ghaem, MOTOROLA



Semiconductor Film Deposited on View Foil



2D array
using CdSe

CdSe deposited on view foil

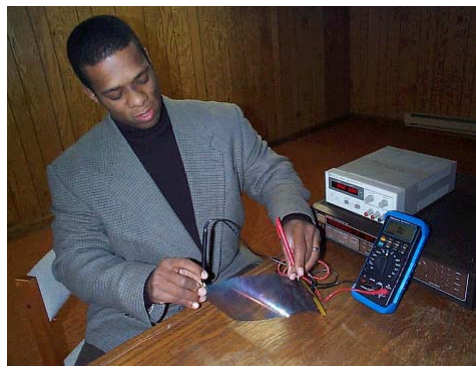


- Room temperature process
- Large variety of substrates possible
- Large areas can be covered
- Contacts demonstrated
- Device building blocks are under development

shur@b-i-ts.com
Michael Shur, RPI

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Cu_xS films on flexible substrates



By adjusting the concentrations of Cu^+ ions and Na_2S_n poly-sulfide and by using multiple deposition cycles we obtained metal CuS films with the resistivity as low as 100 ohm per square. The deposited thin films exhibited excellent adhesion to the polymeric substrate/film

Michael Shur, RPI

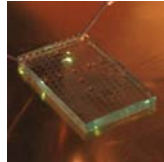
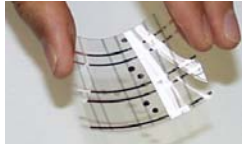


Flexible Active Electronics

We have fabricated a variety of active electronic devices and circuits on flexible substrates, including organic circuits based on pentacene, a-Si:H circuits, mixed organic/inorganic pentacene/a-Si:H complementary circuits, and organic light emitting devices. Control and logic backbone for sensitive skin?

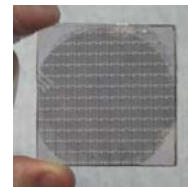


a-Si:H thin film transistors and circuits on Kapton and on colorless polyimide



Organic light emitting devices on flexible PET foil

Pentacene organic thin film transistors and integrated circuits on Kapton and on flexible PET foil



Human-Robot Exploration - Needs and Questions

- **Robotics specialists** need appreciation of human issues: psychology, cognition, fatigue, acceptance, rejection, style, learning, logic, spatial reasoning
- **Cognitive science research:** understanding limits of human cognitive skills - spatial, logical, temporal - when manipulating physical objects
- **Extensive research** needed to make tele-presence a reality
- **Extensive research** needed to realize whole-body sensing
- **Algorithmic work** needed on related robot intelligence